TACTICAL VISUALIZATION OF THE ENVIRONMENT: MANTA MINEFIELD SEARCH

Don Brutzman, Assistant Professor
Undersea Warfare Academic Group
Anthony Healey, Professor
Department of Mechanical Engineering
Center for Autonomous Underwater Vehicle Research
Sponsor: Naval Undersea Warfare Center-Newport

OBJECTIVE: The purpose of this project is to demonstrate how tactical visualization of real-world environments can provide significant insights into robot system development and tactical deployment.

SUMMARY: To illustrate the power of tactical visualization, Manta robot submarines are shown how they might bring new and needed capabilities to the fleet. A meaningful tactical scenario was developed around four Manta robots being deployed from a host submarine. A scalable Web-based approach to 2D and 3D visualization is presented using the Hypertext Modeling Language (HTML) and the Virtual Reality Modeling Language (VRML). Extensive analytic simulation of multiple tactics versus multiple minefield types provides a useful methodology and tangible minefield mapping results for robots. Finally, utilizing an underwater virtual world and existing robot software for the NPS *Phoenix* autonomous underwater vehicle (AUV) ensures that all results are feasible using today's technology. Ongoing unfunded work includes a Java-VRML library for real-time 3D visualization of sonar beams.

CONFERENCE PRESENTATION:

Brutzman, D.P., Chan, E., Evans, M., Holliday, T., Huck, M., Jezek, R., Ma, B.-B., Murley, S., Toland, R., and Yee, Y., "Minefield Search Tactic Evaluation Using Four Autonomous Manta UUVs," Symposium on Technology and the Mine Problem, Naval Postgraduate School, Monterey CA, 6-10 April 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Tactical Visualization, Manta Submarines, Virtual Worlds, AUV, Minefield Search

AUTONOMOUS UNDERWATER VEHICLE (AUV) DEVELOPMENT

Don Brutzman, Assistant Professor
Undersea Warfare Academic Group
Anthony Healey, Professor
Department of Mechanical Engineering
Center for Autonomous Underwater Vehicle Research
Sponsor: Unfunded

OBJECTIVE: To solve open problems in underwater vehicle control to dock an AUV with a tube in the presence of time-varying turbulent flow fields.

SUMMARY: Algorithms have been developed and tested for sensing, maneuvering, and precise control relative to a docking station. Sensing and maneuverability have been demonstrated in the presence of turbulent cross-body flow using the AUV virtual world. This effort addresses a significant problem facing AUVs where success has broad implications. Distributed analog/digital device control using the LONTALK protocol has also been demonstrated. An ongoing dialog with researchers in the French Navy has proven productive, with graduate students visiting and working at NPS.

PUBLICATION:

Brutzman, D., Healey, A., Marco, D., and McGhee, R., "The *Phoenix* Autonomous Underwater Vehicle," *AI-Based Mobile Robots*, eds: David Kortenkamp, Pete Bonasso and Robin Murphy, MIT/AAAI Press, Cambridge MA, 1998.

CONFERENCE PRESENTATION:

Brutzman, D., "Tutorial: Virtual World for an Autonomous Underwater Vehicle (AUV)," IEEE Oceanic Engineering Society Conference OCEANS 97, Halifax Nova Scotia, October 1997.

THESIS DIRECTED:

Young, F.C., "*Phoenix* Autonomous Underwater Vehicle (AUV): Networked Control of Multiple Analog and Digital Devices Using LONTALK," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles – Ships and Watercraft, Modeling and Simulation, Sensors, Computing and Software

KEYWORDS: Autonomous Underwater Vehicle, Robot, AUV, Control, Virtual Worlds

RAPIDLY RECONFIGURABLE VIRTUAL ENVIRONMENT NETWORK PROTOCOLS

Don Brutzman, Assistant Professor
Undersea Warfare Academic Group
Michael Zyda, Professor
Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: To create a formally specified behavior protocol that permits scalable inter-entity interactions to be defined, modified, and tested while large-scale exercises are in progress.

SUMMARY: Construction of a Distributed Interactive Simulation (DIS) library in the *Java* language has been continued and hooks are being created to generic 3D scenes drawn using the Virtual Reality Modeling Language (VRML). Completed thesis work shows how to formally specify protocol data unit (PDU) elements and subsequently autogenerate reader/writer source code. The new DIS library will be extended to permit on-the-fly modification in mid-exercise, permitting experimental optimization of behavior protocols and overcoming a key DIS deficiency. This functionality will be implemented as Area of Interest Manager (AOIM) applets or agents (i.e., mobile executable code) which consolidates multicast channel selection, subscription and desubscription of network streams, either for individual hosts or local-area networks (LANs). This is an ongoing project, which also supports the virtual reality transfer protocol (vrtp) research.

PUBLICATIONS:

Brutzman, D., "Graphics Internetworking: Bottlenecks and Breakthroughs," Chapter, *Digital Illusions*, ed: Clark Dodsworth, Addison-Wesley, Reading Massachusetts, 1997.

Rhyne, T.-M., Brutzman, D., and Macedonia, M., "Internetworked Graphics and the Web," *IEEE COMPUTER*, Vol. 30, No. 8, pp. 99-101, August 1997.

CONFERENCE PRESENTATION:

Brutzman, D., Zyda, M., Watsen, K., and Macedonia, M., "Virtual Reality Transfer Protocol (vrtp) Design Rationale," Workshops on Enabling Technology: Infrastructure for Collaborative Enterprises (WET ICE): Sharing a Distributed Virtual Reality, Massachusetts Institute of Technology, Cambridge MA, 18-20 June 1997.

OTHER:

McGregor, D. and Brutzman, D., *DIS-Java-VRML Working Group.*

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Large-Scale Virtual Environments (LSVEs), Network Protocols, Multicast, DIS

DATA ANALYSIS FOR THE SWARM EXPERIMENT

Ching-Sang Chiu, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this research is to characterize the internal waves and their impact on the spatial and temporal variability and coherence of acoustic transmissions in a shelf environment.

SUMMARY: During the summer of 1995, a multi-institutional field study called Shallow Water Acoustics in a Random Medium (SWARM) was conducted in the Mid-Atlantic Bight continental shelf region off the coast of New Jersey. Environmental and acoustic sensors were deployed as part of SWARM to measure and characterize the non-linear internal waves and their impact on the spatial and temporal coherence of the acoustic transmissions. As part of the environmental monitoring network, two bottom-moored, upward-looking Acoustic Doppler Current Profilers (ADCPs) were deployed. An oceanographic, modal, time-series analysis of the ADCP data reveals that: large-amplitude, nonlinear, internal wavepackets were generated at multiple sites near the shelfbreak; the generation mechanism was consistent with the lee-wave hypothesis of generation; the propagation characteristics were in good agreement with nonlinear soliton theory; and the power spectral density was spatially varying and changed markedly during the passage of these nonlinear waves. Based on these observations, a model of the induced sound-speed perturbations was developed. Using a coupled normal-mode propagation model, the temporal and vertical structure of the sound field were subsequently calculated for comparison to data obtained by a vertical line array.

PUBLICATIONS:

Chiu, C.-S., Ng, S.-L., and Denner, W.W., "Estimating the Properties of the Sound Field in a Shelf Region near the Shelfbreak," *Proceedings of the 6th Western Pacific Regional Acoustics Conference*, Vol. 1, pp. 329-334, 1997.

Apel, J., Badiey, M., Chiu, C.-S., Finnette, S., Headrick, R., Kemp, J., Lynch, J., Newhall, A., Orr, M., Pasewark, B., Tielbuerger, D., Turgut, A., von der Heydt, K., Wolf, S., "An Overview of the 1995 SWARM Shallow Water Internal Wave Acoustic Scattering Experiment," *IEEE Journal of Oceanic Engineering*, 22(3), 465-500, 1997.

CONFERENCE PRESENTATIONS:

Chiu, C.-S., Ng, S.-L., and Denner, W.W., "Estimating Properties of the Sound Field in a Shelf Region near the Shelfbreak," 6th Western Pacific Regional Acoustics Conference, Hong Kong, 19-21 November, 1997.

Apel, J., Badiey, M., Chiu, C.-S., Finnette, S., Headrick, R., Kemp, J., Lynch, J., Newhall, A., Orr, M., Pasewark, B., Tielbuerger, D., Turgut, A., von der Heydt, K., Wolf, S., "The New Jersey Shelf Shallow-Water Acoustic Random Media Propagation Experiment (SWARM)," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997.

Apel, J., Chiu, C.-S., Headrick, R., Lynch, J., Orr, M., Pasewark, B., and Wolf, S., "Acoustic Travel Time and Intensity Fluctuations Measured in the 1995 SWARM Experiment," 133rd Meeting of the Acoustical Society of America, State College, PA, 15-20 June 1997.

THESIS DIRECTED:

Ng, S.-L., "A Simulation Study of Acoustic Variability due to Internal Solitary Waves on the Mid-Atlantic Continental Shelf," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: Littoral, Acoustics, Internal tides, Internal waves

MIDDLE ATLANTIC BIGHT (SHELFBREAK PRIMER) FIELD STUDY

Ching-Sang Chiu, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVES: The objectives of this multi-year, multi-institutional field study in the Middle Atlantic Bight are to improve the understanding of the physical variability of the shelf break front south of New England, and to apply this improved knowledge to problems in acoustical propagation. To do this, detailed measurements have been made of physical and acoustical properties during the contrasting summer and winter seasons. These measurements are being related to physical and acoustical modeling studies. Results from these modeling efforts, tested against the observations, should be broadly applicable to shelf-break regions on a more global basis.

SUMMARY: The field programs surveying the frontal region have been concluded. The field work included two intensive three-week experiments, one in July 1996 (summer) and the other one in February 1997 (winter). Specifically, each of the two experiments successfully employed a suite of observational techniques including an acoustic tomography array consisting of multiple transceivers/sources and two vertical hydrophone arrays (VLAs) straddling the shelf-break front, several high-resolution, three-dimensional surveys of the frontal region with a SeaSoar, a shelf-to-slope hydrographic section, and moored arrays of ADCPs, current meters and thermistors. The resultant data set is both comprehensive and of high quality, and will allow for gaining fundamental insights into the oceanographic processes which influence acoustic propagation in a slope-shelf region. The measurements are being supplemented by model studies, both oceanographic and acoustic. The detailed analysis of the data and the modeling has begun in earnest, with an initial emphasis being upon understanding the oceanographic field through which the acoustic signals have propagated.

NPS plays a lead role in all phases of the study including experimental planning, data collection, data processing, acoustic modeling, and data analysis. Specifically, NPS has initiated modal processing, modeling, and time-series analysis of the acoustic data in an effort to quantify the dominant space and time scales of the variability in the sound field and to relate the observed acoustic variability to ocean processes.

PUBLICATIONS:

Chiu, C.-S., Miller, C.W., and Lynch, J.F., "Optimal Modal Beamforming of Bandpass Signals Using an Undersized, Sparse Vertical Hydrophone Array: Theory and a Shallow-Water Experimentation," *IEEE Journal of Oceanic Engineering*, 22(3), 522-533, 1997.

Lynch, J.F., Gawarkiewicz, G.G., Chiu, C.-S., Pickart, R., Miller, J.H., Smith, K.B., Robinson, A., Brink, K., Beardsley, R., Sperry, B., and Potty, G., "Shelfbreak PRIMER - An Integrated Acoustic and Oceanographic Field Study in the Mid-Atlantic Bight," *Proceedings of the International Conference on Shallow-Water Acoustics*, Beijing, China, 1997, in press.

CONFERENCE PRESENTATIONS:

Chiu, C.-S. and Lynch, J. F., "Acoustic Tomography in Shallow Water," International Workshop on Ocean Acoustic Tomography, Yokosuka, Japan, 13-14 March 1997.

Chiu, C.-S., Miller, C.W., and Lynch, J.F., "Optimal Modal Beamforming of Bandpass Signals Using an Undersized, Sparse Vertical Hydrophone Array: Theory and a Shallow-Water Experimentation," 3rd International Conference on Theoretical and Computational Acoustics, Newark, NJ, 14-18 July 1997.

Chiu, C., "Measurement and Analysis of the Propagation of Sound from the Continental Slope to the Continental Shelf," 134th Meeting of the Acoustical Society of America, San Diego, CA, 1-5 December 1997.

Gawarkiewicz, G.G., Pickart, R., Lynch, J.F., Chiu, C.-S., Smith, K.B., and Miller, J.H., "The Shelfbreak Front PRIMER Experiment," 133rd Meeting of the Acoustical Society of America, State College, PA, 15-20 June 1997.

Beardsley, R.C., Brink, K.H., Caruso, M.J., Chiu, C.-S., Gawarkiewicz, G.G., Lynch, J.F., Miller, J.H., Pickart, R., Robinson, A.R., and Smith, K.B., "Shelfbreak PRIMER - An Integrated Acoustic and Oceanographic Field Study in the Middle Atlantic Bight," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: Littoral, Acoustics, Nowcast, Shelfbreak Fronts

MONITORING WHALES USING THE PT. SUR ACOUSTIC ARRAY - A FEASIBILITY STUDY

Ching-Sang Chiu, Associate Professor
Curtis A. Collins, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVES: The objectives include: (1) to investigate the feasibility of locating and tracking distant California blue whales using a former SOSUS array and matched signal algorithms; (2) to explore the possibility of providing supplementary information on counts and transit paths of California blue whales; and (3) to enhance the understanding of low-frequency sound propagation physics in a littoral environment.

SUMMARY: Detecting, classifying, localizing, and tracking vocalizing whales using receiver arrays at long ranges is a complex problem. It is a combined signal processing-acoustics-oceanography problem. First, knowledge of the loudness and frequency-time distribution of the different whale sounds is required for classification purposes. Equally important is the understanding of the basic structure and variability of the ocean sound channel. The ocean scrambles the vocalized signal by its multipaths as the signal propagates to a distant receiver. The ability to predict the mean and variance of the propagation is thus required to unscramble the received signal and to constrain the uncertainty.

In the summer of 1997, two three-day experiments were conducted to test the feasibility of acoustically detecting, classifying, localizing, and tracking blue whales at long ranges using a former SOSUS listening array located at the Naval Postgraduate School Ocean Acoustic Observatory (OAO) at Pt. Sur, CA. During each experiment, full-array data were archived continuously at the OAO. In concert with the shore-based acoustic monitoring, an aircraft was assigned to locate blue whales in the Monterey Bay National Marine Sanctuary and to direct a research vessel to a whale site. The research vessel was manned with observers and instrumented with a towed hydrophone array to ground-truth the locations of the

blue whales and classify the vocalized near-field signals. These shipboard measurements were required to provide a means to separate the source signal characteristics from the multipath signatures for the calibration and validation of broadband, model-based localization methods. Initial experimental as well as modeling results show great promise, which included assessments of the predictability, i.e., variability, of the vocalized sound and the uniqueness of the location-dependent multipath structure. Both are fundamental to the applicability of model-based algorithms.

CONFERENCE PRESENTATION:

Chiu, C.-S., Collins, C.A., Hager, C.A., Miller, C.W., Moore, T.C., Rocheleau, M.R., Lashkari, K., and Hayes, S., "A Feasibility Field Study of Monitoring Blue Whales Using the Pt. Sur Ocean Acoustic Observatory," 134th Meeting of the Acoustical Society of America, San Diego, CA, 1-5 December, 1997.

THESIS DIRECTED:

Hager, C.A., "Modeling the Performance of the Pt Sur Hydrophone Array in Localizing Blue Whales," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: Coastal, Acoustics, Whale Monitoring, Alternate Uses

INTERNATIONAL CONFERENCE IN SHALLOW-WATER ACOUSTICS

Ching-Sang Chiu, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVES: The long-term goal is to formulate and conduct a collaborative international experiment in the seas of China. Such an experiment will focus on studying the physics and variability of sound propagation and scattering that are unique to the coastal waters of the Asian Pacific region. The FY97 objective was to promote scientific exchange and establish a dialog between Asian and U.S. scientists who are active in shallow-water acoustics research.

SUMMARY: The approach was to hold an international conference in Beijing, China as a outgrowth from the Office of Naval Research (ONR) USA-China Conference in Shallow-Water Acoustics held at the Naval Postgraduate School in December 1995. An international conference in China could attract many of the top-notch Asian scientists to attend. It could help to establish a dialog between the Asian and U.S. underwater acoustics communities and to provide a forum to exchange and discuss the latest scientific ideas, approaches and results in shallow-water acoustics which might form the basis for future collaborative research efforts between the U.S. and Asian communities.

The Principal Investigator worked closely with the Chinese co-organizers to coordinate the conference logistics, to plan the conference agenda, and co-chair the technical committee, to assist in identifying topics for special sessions, to select invited speakers and session chairs, and to assign contributed papers to the appropriate sessions. He also served on an ONR delegation to visit several oceanographic and acoustic laboratories in China following the conference. The post-conference tour was designed to begin the development of an international steering group to formulate and execute a collaborative field study.

A major accomplishment is that the conference and the post-conference tour have led to a strong dialog with the Chinese, Japanese, Korean, Singaporean, Russian and Indian scientists. An international steering group workshop to investigate the scientific, engineering, and logistic rationales that might form the basis for a collaborative international experiment in the seas of China is now in the planning.

PUBLICATION:

Chiu, C.-S. and Lynch, J.F., "Acoustic Tomography in Shallow Water: Issues, Methods and Experimental Results," *Proceedings of the International Conference on Shallow-Water Acoustics*, 1997, in press.

CONFERENCE PRESENTATION:

Chiu, C.-S. and Lynch, J.F., "Acoustic Tomography in Shallow Water: Issues, Methods and Experimental Results," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: Shallow-Water Acoustics

DEVELOPMENT OF THE PT. SUR OCEAN ACOUSTIC OBSERVATORY

Ching-Sang Chiu, Associate Professor
Department of Oceanography
Sponsors: Scientific AI Corporation, Cornell University, and Office of Naval Research

OBJECTIVES: The objectives are: (1) to preserve the functionality of the Pt. Sur SOSUS horizontal hydrophone array and (2) to convert the facility into a dual-use Ocean Acoustic Observatory for the purpose of undersea research.

SUMMARY: In 1995, the Pt. Sur Ocean Acoustic Observatory in the Monterey Bay National Marine Sanctuary was established for the purpose of undersea research. Several sponsoring organizations have contributed greatly to this commendable community effort. Their contributions were in terms of hardware, reimbursable funding for electric and electronic maintenance, labor, and the conduct of high-quality research using the data.

In 1997, the development of the Pt. Sur Ocean Acoustic Observatory (OAO) was continued using reimbursable funding provided by SAIC, Cornell University, and the Office of Naval Research. The 1997 OAO research projects include nuclear test ban treaty monitoring, coastal ocean circulation studies, and marine mammal studies. The latest accomplishment is the development of a full-array classified data archival capability. This enhanced capability will enable the conduct of both classified and unclassified research that require spatial beamforming using the horizontal array.

THESES DIRECTED:

Morvillez, T., "Monitoring Temperature Variability Along the California Coast Using Acoustic Tomography," Master's Thesis, Naval Postgraduate School, September 1997.

Smith, A., "Analysis of Modal Travel Time Variability due to Ocean Mesoscale Structure," Doctor of Philosophy Dissertation, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: SOSUS, Alternate Uses, Acoustic Observatory

SURF ZONE SEISMO ACOUSTICS
Thomas Muir, Chair of Mine Warfare
Undersea Warfare Academic Group
Stephen Baker, Associate Professor
Department of Physics
Sponsor: Office of Naval Research

OBJECTIVE: To provide the U.S. Navy and Marine Corps with a seismic sonar technology which will enable the detection of enemy mines that are buried in sea floor and beach sediments. This work is a continuation of prior research conducted by the senior principal investigator at the Laboratory of the NATO Supreme Atlantic Commander's Undersea Research Centre in La Spezia Italy and at the Applied Research Laboratory of the University of Texas at Austin. This research was ported to NPS in 1997, when Professor Muir became the Ellis A. Johnson Chair Professor of Mine Warfare. This work was originally sponsored by NATO, then transitioned to the ONR basic research program, and has now transitioned to ONR's exploratory research program, both in ONR Code 321 under Program Managers Dr. Jeffrey Simmen and Dr. Douglas Todoroff, respectively.

SUMMARY: The concept of an active, seismic sonar for the detection of mines buried in the surf and near surf zone was investigated. Electromechanical transducers having two, controllable degrees of freedom were developed to selectively excite seismic interface waves that travel along the air or water boundary with the sediments. These interface waves were caused to reflect off buried mines, and the received echoes were detected in such a way as to determine the range and bearing of the buried targets from the sonar. Signal processing of the seismic echo fields were developed to enhance the received target echoes and suppress the noise and reverberation. These procedures were tested in experiments done at the beach across from the Naval Postgraduate School.

PUBLICATIONS:

Muir, T.G., et al., "Seismic Interface Wave Sonar," *Proceedings of the Third Technological Conference of Underwater Acoustics*, The Institute of Marine Research of the Brazilian Navy, Ilha do Governador, Rio de Janerio, Brazil, 23-24 September 1997.

Muir, T.G., et al., "Experiments on the Seismic Detection of Buried Objects," *Journal of the Acoustical Society of America*, American Physical Society, December 1997, accepted for publication.

CONFERENCE PRESENTATION:

Muir, T.G., "Seismic Interface Wave Sonar," Third Technological Conference of Underwater Acoustics, Institute of Marine Research of the Bazilian Navy, Ilha do Governador, Rio de Janerio, Brazil, 23-24 September 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Mine Warfare)

KEYWORDS: Mine Detection, Seismic Sonar

SUBMARINE SECURITY
Alan R. Washburn, Professor
James Eagle, Professor
Undersea Warfare Academic Group
Sponsor: Office of Naval Research

OBJECTIVE: This project is to familiarize the principal investigators and other NPS faculty with submarine security issues, the intention being to effect a more intense cooperation in future years. Travel to Johns Hopkins University/Applied

Physics Laboratory (JHU/APL) is intended as a first step. Other efforts include support in defining the problem, developing or identifying analytic approaches, reviewing studies, and conducting independent studies. The principal investigators have extensive experience in systems studies involving submarines, particularly where search theory is involved.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Submarine, Security, Effectiveness

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